

Hole Cyclotron Resonance in a Ferromagnetic InMnAs/GaSb Heterostructure

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InMnAs films and their heterostructures with (Al,Ga)Sb, the first grown III-V dilute magnetic semiconductor (DMS) system [1], serve as a prototype for implementing the spin degrees of freedom. When a high density of holes exists, these semiconductors become ferromagnetic [2,3]. Understanding their electronic and optical properties is crucial for designing novel spin-based devices with high Curie temperatures. We have recently reported the first observation of *electron* cyclotron resonance (CR) in a series of *n*-type *paramagnetic* In_{1-x}Mn_xAs films on GaAs [4]. In this paper, we report the first observation of *hole* CR in a *p*-type *ferromagnetic* InMnAs/GaSb heterostructure. Our results provide much new insight into the *mechanism of hole-mediated ferromagnetism* in III-V DMSs.

Shown in Fig. 1 is a schematic band diagram of the sample we studied. The thickness of the InMnAs layer was 9 nm. Due to the unusual type-II band lineup plus the surface pinning of the Fermi energy, there are two “pockets” where holes are quantum mechanically confined—one pocket on the InMnAs side and the other on the GaSb side of the interface. Figure 2 shows typical CR data taken with a 10.6-micron laser beam at various temperatures. There are three groups of traces here: The top three traces – “high-T regime”; the 77K trace – the transition from the high-T regime to the low-T regime; the lowest 2 traces – “low-T regime.” The transition between the high-T and low-T behavior is very abrupt and cannot be attributed to simple thermal bound-to-free activation behavior of holes.

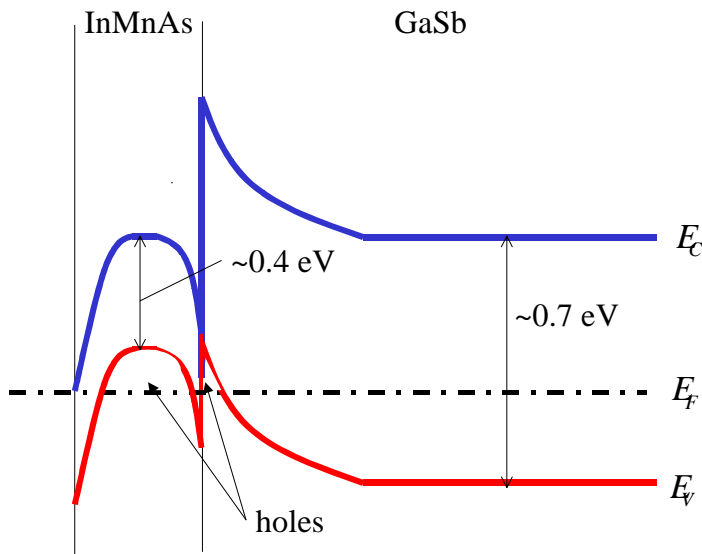


Fig. 1 Schematic band diagram of the structure.

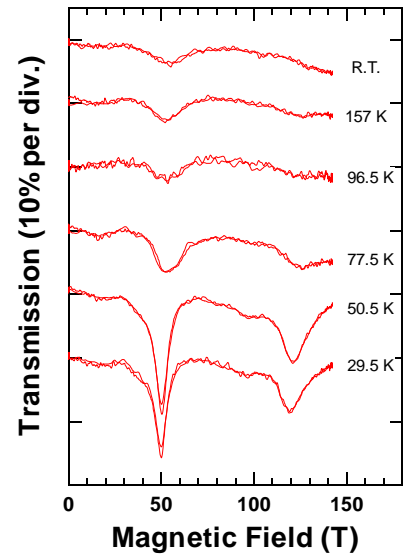


Fig. 2 Typical cyclotron resonance data.

We compare these results with detailed calculations. Nonparabolicity due to the strong coupling between valence and conduction bands is incorporated using a modified 8x8 Pidgeon-Brown model. The effects of the Mn doping via the sp-d exchange interaction between the magnetic Mn impurities and the electrons and holes are also included. We calculate the effective masses and g factor as a function of Mn doping.

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